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HASC STAFF INQUIRY

INTO THE BRADLEY

LIVE FIRE TEST PROGRAM

MAY 1986

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HASC Staff Inquiry Into The

Bradley Joint Live Fire Test Program

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INTRODUCTION

A. Allegations

On April 15, 1986 Col. James G. Burton, Director of the Joint Live Fire Test Program, Office of Director of Defense Test and Evaluation, promulgated a memorandum that alleged a number of irregularities in the testing of the Bradley Fighting Vehicle as part of the Joint Live Fire Test program. Specifically, Colonel Burton charges:

1. Water cans were repositioned on the Bradley so "they were directly behind the impact point and on the shot line for shot 1." He states that "switching of ammunition and water can location changes only the test results, not the actual vulnerability in combat."

2. The Army has ignored guidance that additional Phase II shots be selected by random draw from combat hit distribution to prevent personal or systematic bias from entering the picture.

3. Specific Phase II aim points and shot lines have been intentionally selected to generate specific effects. "Eight of the planned 34 Phase II shots are aimed at the repositioned water cans." So when a round penetrates Bradley armor, it will strike water cans, thereby minimizing behind-armor damage.

4. "Since 1984 there has been a pattern of key BRL [Ballistic Research Laboratory] attempts to reduce the apparent casualties caused by the Bradley during tests...."

On April 17, 1986 that memorandum and several other documents were released during a press conference given by Members of Congress.

One of these documents also raises the issue of the Minimum Casualty Baseline Vehicle. Colonel Burton alleges the Army made a commitment to test his concept of a Bradley that stows ammunition and fuel outside the vehicle. Colonel Burton believes that crew casualties as a result of explosions and fire would be reduced with this vehicle configuration. He believes the Army is purposely delaying the test of this concept because it does not want any competition with one of its Phase II enhancements--the reactive armor concept.

As a result of the concerns expressed by members of the House Armed Services Committee, the staff was directed to conduct an investigation into the allegations described above and to examine the effectiveness of the Joint Live Fire Test Program in overseeing the Bradley tests.

B. Scope of the Investigation

The investigative team was composed of staff members representing the Subcommittees on Research and Development, Procurement, Investigations, and Seapower. The team focused its examination on the results of Phase I tests, testing methodology in the planning and execution of Phase II tests, the Office of the Secretary of Defense's (OSD) Minimum Casualty Vehicle, and the Live Fire Test Program policies and procedures as they relate to execution of the Bradley

testing program. The team also conducted a preliminary inquiry into the circumstances surrounding Colonel Burton's transfer.

The investigative team interviewed officials in the Office of the Under Secretary of Defense for Research and Engineering; the Under Secretary of Defense for Acquisition and Logistics; the Under Secretary of the Army; the Deputy Under Secretary of the Army for Operations Research; officials in the Office of the Deputy Chief of Staff for Research, Development and Acquisition; the Office of the Surgeon General of the Army; the Army Materiel Command; the General Accounting Office; the Institute for Defense Analysis; and a private consultant. A list of all persons interviewed is appended to this report.

SUMMARY

A. Background

The Joint Live Fire Test Program was initiated in 1983 at a modest level with the stated purpose of testing the lethality of U.S. weapons against combat-configured Soviet vehicles and of determining (and of correcting where possible) the vulnerabilities of combat-configured U.S. vehicles to Soviet weapons. Prior to that time, the assessment of vulnerabilities was based, for the most part, on computer analysis with few full-scale test results to support the assessments.

The Army in 1983 nominated the Bradley as one of their candidates for testing. There are two versions of the vehicle--the M-3 scout (5-man) and M-2 infantry (9-man). The Army chose to test the M-3 version.

The testing program was composed of two phases.

The priority test objective for Phase I tests on the Bradley was to quantify the lethality of major caliber anti-armor munitions, often referred to as overmatching weapons (i.e., munitions capable of breaching the vehicle's armor), against the Bradley's armor. In addition, Army officials wanted to collect data to update their predictability models.

In carrying out the Phase I testing program, a building block approach was advocated and used by the Army. Testing commenced with controlled firings at Bradley components and at production M-3 vehicles containing inert ammunition. These tests focused on individual areas of the vehicle in order to gain a better understanding of the complex interrelationships involved in modeling the effects of weapons on the Bradley and to identify improvements needed in the models used to estimate the overall vulnerability of the weapon system (based on data from selected firings). Phase I testing concluded with 10 firings at M-3 vehicles containing live ammunition. These shots addressed remaining uncertainties--the reaction of fuel and ammunition and other synergistic effects that may occur during full-up tests.

The objective of Phase II was to test the best possible means of reducing the sources of Bradley casualties revealed during the Phase I tests. In Phase II the Army specified a number of enhancements--reactive armor, spall liners, limited movement of ammunition--that would be tested. The outline test plan specified 34 total shots (17 each on 2 test vehicles), of which 14 would be repeats of Phase I shots, and 20 were to be into areas where enhancements were made.

On March 20, 1986 Phase II testing began. Primarily because of Colonel Burton's April 15 memorandum, Phase II testing was suspended on April 18, 1986, after eleven shots had been completed.

The irregularities cited by Colonel Burton are traceable to the beginning of the Bradley Live Fire Test Program. The Army and Colonel Burton have

fundamental disagreements over testing methodologies and how the program should be run. Most of the issues on testing methodology raised by Colonel Burton should have been resolved by a higher decision-making level prior to initiation of the testing program. Because the issues were not resolved, the investigative team questions the adequacy of the overall policy regulating the Joint Live Fire Test program and the effectiveness of its management within the framework of developmental testing and evaluation. The team sees broader implications of the failures in the Bradley Joint Live Fire Tests for other testing program areas.

The report addresses the issue of lack of policy guidance as the overarching problem in the conduct of the Bradley Joint Live Fire Tests and then addresses the specific allegations. Because of the interrelationship among some of the allegations, more than one allegation may be discussed in the same section of the report.

B. Findings and Conclusions

1. Lack of Policy Guidance for the Joint Live Fire Test Program

a. Analysis

No specific Department of Defense (DOD) regulations prescribing policy and procedures for the conduct of the Joint Live Fire Test program exist. Although general agreement exists on the overall goals of the program, the understanding of how the program is to be run and what the test methodology is to be varies. DOD Directive 5000.3, specified as the guidance for the tests, makes no mention of the Joint Live Fire Test program. A Detailed Test Plan submitted by the service and approved by OSD is supposed to serve as the formal procedural document for conduct of the test, but no such detailed test plan for the Phase II test of the Bradley was ever approved by OSD.

Because a Detailed Test Plan was never submitted or approved, many contentious issues regarding the test program (such as shot selection and testing methodology, and the requirement to test the Minimum Casualty Vehicle) were never resolved. Phase II tests were begun--in fact, eleven shots were conducted before the program was suspended--without a Detailed Test Plan.

To further complicate policy and procedural problems, in 1984 OSD decided that the Bradley tests would be conducted by the Army outside the framework of the Joint Live Fire Test program, and Colonel Burton was invited to participate in the planning and execution of the tests.

b. Conclusions

-- In 1984 OSD decided to remove the Bradley vulnerability test program from the OSD Joint Live Fire Test Program, for funding and schedule considerations.

-- The Army began the test program without an OSD-approved Detailed Test Plan. In the absence of an approved test plan, the Phase II tests never should have commenced.

-- Policies and procedures for the conduct of the Bradley Live Fire Test are ill-defined and not formalized.

-- The Army will not complete Phase II testing in time to report to Congress by June 1, as required by the fiscal year 1986 Department of Defense Authorization Act.

2. Allegations 1 and 3

a. The Allegations

Allegation 1. Water cans were repositioned on the Bradley so "they were directly behind the impact point and on the shot line for shot 1." He states that "switching of ammunition and water can location changes only the test results, not the actual vulnerability in combat."

Allegation 3. Specific Phase II aim points and shot lines have been intentionally selected to generate specific effects. "Eight of the planned 34 Phase II shots are aimed at the repositioned water cans." So when a round penetrates Bradley armor it will strike water cans, thereby minimizing behind-armor damage.

b. Analysis

Colonel Burton's allegations with regard to the switching of water cans and ammunition raise the issue of whether the relocation and subsequent test shot selection reflect a purposive decision by the Army to obtain test results that would make the Bradley appear less vulnerable than it actually would be in its operational mode. Fundamental to this issue is the determination of, first, whether, if rounds hit the water cans, the damage to the vehicle would be significantly less and, second, whether the expected combat distribution of hits would result in more rounds striking the water cans after the relocation.

Two days prior to beginning the Phase II tests, the location of two five-gallon water cans and ammunition boxes were switched. The two five-gallon water cans were repositioned from the left rear to the left center of the vehicle. Army officials base this repositioning on a philosophy that, to the extent possible, ammunition and fuel should be stowed away from the center mass of the vehicle because this is the target area of trained enemy gunners. A September 1984 engineering diagram for an updated version of the vehicle tested (M3A1) documents this positioning for future production versions and a "Subjective Analysis" conducted by the Ballistic Research Laboratory in July 1984 supports the Army's rationale for this decision.

No one disputes that if a round hits a water can the damage to the vehicle would be less than if a round does not hit a water can.

Colonel Burton believes very little decrease in vulnerability would be achieved as a result of repositioning the water cans. His position is supported by a study conducted by the Institute for Defense Analysis that uses combat data and that estimates only a slight increase in the probability of a hit in the water cans by relocating them to the center of the side of the vehicle.

With reference to Colonel Burton's charge that eight of 34 Phase II shots are aimed at the repositioned water cans, because no Detailed Test Plan has been promulgated, no information is available to determine unambiguously the number of shots that may impact the water cans. The Ballistic Research Laboratory provided a diagram depicting their shot scheme which shows only two shots (one shot on each test vehicle) directly impacting the water cans. Colonel Burton bases his view on visual observation and the corresponding shot scheme shown in the outline test plan. Neither diagram is sufficiently detailed to measure impact points precisely.

c. Conclusions

-- No documentation of the decision to move the water cans immediately prior to Phase II tests to the left center side of the test vehicle was obtained by the investigative team. However, the repositioning was in accordance with 1984 Army engineering diagrams for the M3A1 and the Army stowage philosophy.

-- Independent analysis concludes that the repositioning of the water cans would have little impact on the Bradley vehicle's overall vulnerability in combat.

-- The investigative team was not able to determine with certainty the number of test shots directed at the water cans. The team concludes, however, that to remove any possibility of bias and in view of the limited number of shots, no shots should have been directed in the vicinity of the water cans, regardless of their location on the vehicle.

3. Allegation 2

a. The Allegation

The Army has ignored guidance that additional Phase II shots be selected by random draw for combat hit distribution to prevent personal or systematic bias from entering the picture.

b. Analysis

Several fundamental differences exist between the testing methodologies of the Army and Colonel Burton. The Army prefers a systematic building block approach to testing; Colonel Burton advocates immediate full-up shots of combat loaded vehicles. Also, the Army and Colonel Burton have a fundamental disagreement over whether shots should be selected at random or directed into specific areas.

Depending on the results desired, both methodologies are based on sound testing philosophies and are fully supportable if supporting data is used to fully represent the outcome. Two independent organizations, the Los Alamos National Laboratory and the Institute for Defense Analysis, have examined aspects of shot selection methodologies. Los Alamos concludes that a combination of the two methodologies be used. The Institute for Defense Analysis would prefer more randomness in shot selection but says more shots would be needed to obtain a meaningful result.

Regardless of the methodology selected, the Joint Live Fire Test Program specifies use of vulnerability lethality models as the method to evaluate prudently system vulnerability. Colonel Burton relies less on models than on random full-up shots and does not believe the Army models are good predictors. The Army believes shot selection directed to specific areas and adequate preliminary component testing prior to full-up shots should be used to update model data. The updated model is then used as the primary tool for predicting vulnerability. The Institute for Defense Analysis also concluded that the Army's overall method of selecting aim points is not representative of combat hit distribution.

These issues should have been resolved long before the initiation of Phase II testing. Because OSD had not provided formal direction on shot selection methodology to the Army and because the Army initiated the test program without an OSD-approved Detailed Test Plan, these issues were never resolved. These disputes continue today.

c. Conclusions

-- In the review of the Phase II testing, no evidence of intent to bias the test results was found. The Army's test methodology employs specific directed shots. The team observes that live fire test results reported alone do not truly represent Bradley vulnerability. Live fire test results, on the other hand, which are used to update vulnerability models, present a more realistic assessment of the vehicle's vulnerability.

-- The Army and Colonel Burton are in basic disagreement over Live Fire Testing methodology. The Army's attempts to incorporate Colonel Burton's guidance in using Combat Hit Distribution in their testing program has lead to a hybrid shot selection method that cannot be logically supported. The Army has concentrated all Phase II add-on shots at the center of exposed mass of the

vehicle. This concentration is not representative of combat hit distributed impacts, according to an independent analysis of 1973 Arab-Israeli war data.

-- Prior to initiation of Phase II tests, no written OSD guidance was provided directing the use of random shot selection.

-- OSD guidance dated April 1, 1986 indicates that the Army's shot selection was not acceptable. Therefore, the tests should have been suspended by OSD on or about that date.

4. Allegation 4

a. The Allegation

"Since 1984 there has been a pattern of key Ballistic Research Laboratory attempts to reduce the apparent casualties caused by the Bradley during tests...."

b. Analysis

The investigative team was unable, during its investigation, to explore fully all of Colonel Burton's assertions in this area. Of those allegations investigated--shot selection methodology and interior stowage of water and ammunition and related issues--the team found that if a pattern developed, it was one of a long-standing fundamental disagreement over testing methodology and, more importantly, the inability of OSD and the Army to reach an agreement on how the test is to be conducted.

A June 14, 1984 memorandum from Colonel Burton to Deputy Under Secretary James Wade notes,

"Over the course of the past 6-8 months, Ballistic Research Laboratory has made decisions and taken actions in the conduct of this program which, when viewed as a whole, have resulted in less realism than we requested as a condition of [the Army] funding the test, less realism than was easily achievable under the circumstance, and less realism than is needed if any meaningful conclusions are to be drawn with respect to aluminum vaporifics, infantry casualties and the overall combat vulnerabilities of the M-2/3 and M-113 vehicles. In many cases Ballistic Research Laboratory's decisions and action selectively reduced the severity of the behind armor effects noticed. As a result, Ballistic Research Laboratory analyses and inferences on the meaning of the test results...will necessarily be suspect...."

Appended to the memo is a list of 18 separate actions taken by Ballistic Research Laboratory that Colonel Burton claims reduced the behind-armor effects of the test shots. These include: static detonation of weapons rather than dynamic impacts, using weapons that are too small, down-loading propellant in HEAT rounds, reducing the velocity of weapons by firing them too close, and using selected shots and angles.

On April 24, 1986 Colonel Burton provided the team with a memo that states, in part, "Over the past two years we have had numerous disagreements with the Army over the conduct of the Bradley Live Fire Vulnerability Tests and aluminum 'vaporifics' tests." The memo goes on to list 13 test-related issues that Colonel Burton says the Army eventually agreed to and that were in accordance with the OSD direction. The majority of these issues directly resolve those areas in dispute in the June 1984 memo referred above.

Further investigation would be necessary to fully explore all other allegations of irregularities by Ballistic Research Laboratory charged by Colonel Burton.

c. Conclusions

-- The investigative team believes if a pattern developed, it is one of a long-standing fundamental disagreement over testing methodology and, more importantly, the inability of OSD and the Army to reach an agreement on how the test is to be conducted.

-- The Army has complied with many of Colonel Burton's issues of concern developed over the past several years.

5. Minimum Casualty Baseline Vehicle (MCBV)

a. Analysis

In Colonel Burton's view, the purpose of Phase II is to test the best possible means of reducing the potential casualties revealed in the Phase I test. Thus, he believes that the Army's proposed enhancements should be compared with an OSD conceptual vehicle to determine which concept produces the fewer casualties. Colonel Burton proposed a test configuration where all of the fuel and ammunition would be stored externally. The Minimum Casualty Vehicle is proposed as a test of a concept, not as a configuration for a production vehicle. Colonel Burton also believes that this concept vehicle could be available within three months of its initiation.

The Army says that it is committed to testing the concept of the Minimum Casualty Baseline Vehicle as an approach for making future modifications to the Bradley or for improving future armored vehicles. The Army, however, proposes to test the OSD configuration after the current series of Phase II tests are completed because it believes that eight months would be required to design and build the vehicle.

The Army's original February outline test plan says that the live fire test of the "OSD proposed vehicle configuration" would be part of a Phase IIB program after the enhancements to Army's production Bradley were tested. No specific date is mentioned.

On February 24 OSD approved the outline test plan and stated "No reports should be issued, and no production decision made on the final configuration's changes until test results from this configuration are available and compared to the test results from the configurations proposed in your Outline Test Plan." OSD understood the Minimum Casualty Vehicle would be ready for testing by May 1. When they determined it would not be ready in May, OSD recommended seeking relief from a June 1 reporting requirement to Congress until the Minimum Casualty Baseline Vehicle had been tested.

When the Army submitted its revised outline test plan on March 20, they estimated that a "technology demonstration vehicle based on the OSD concept" could be built and ready for testing in eight months. The Army advocated reporting to Congress on the baseline testing on June 1 and reporting subsequent test results on the Minimum Casualty Baseline Vehicle in February 1987.

This dispute on the length of time to build the Minimum Casualty Baseline Vehicle, when it could be tested, and how to report Phase II results to Congress has yet to be resolved.

b. Conclusions

-- The Army does not envision the Minimum Casualty Baseline Vehicle as a near-term alternative for improving the survivability of the Bradley. The Army's preferred approach is to test the reactive armor concepts and spall liners to support a production decision in March 1987.

-- The Army has not complied with the OSD direction regarding the Minimum Casualty Vehicle. Along with the cancellation of the tests, this contributes to the Army not meeting the congressionally-mandated June 1 reporting date.

6. Colonel Burton's Transfer

On April 17, 1986 Colonel Burton submitted his retirement papers. His decision was based in large part on orders received transferring him to Wright-Patterson AFB, after having spent 16 years in the Washington, D.C. area. His transfer at a time when most routine military moves had been suspended, and his memorandum stating that he was told that he would be fired if any more "telephone calls from congressmen" were received, raise questions on the circumstances surrounding Colonel Burton's transfer.

The investigative team did not have sufficient time to conduct a comprehensive investigation into the circumstances surrounding this transfer. The facts uncovered during the preliminary inquiry would support a full investigation by the DOD Inspector General.

7. Recommendations

The committee may wish to direct that:

1. The Bradley vulnerability tests be placed back into the Joint Live Fire Test Program for administrative purposes.

2. No additional testing occur prior to approval of the Detailed Test Plan. The test plan, among other things, should resolve overall test methodology including shot selection.

3. OSD immediately undertake an effort to promulgate regulations implementing OSD guidance on the objectives and procedures for the conduct of the Joint Live Fire Test Program. Joint Live Fire policy should provide for a well-coordinated, approved testing program for the Bradley and other weapon systems programs.

4. The Army be directed to test the concept of the Minimum Casualty Vehicle.

5. No production decisions on reactive armor be made prior to the completion of the Minimum Casualty Vehicle Test and a comprehensive analysis submitted to the Congress.

6. If the concept of the Minimum Casualty Baseline Vehicle is proven as the superior method for reducing casualties, a complete review of the vehicle must be undertaken prior to any production decision.

7. The DOD Inspector General immediately investigate the proposed transfer of Colonel Burton.

8. The Phase II test report be a comprehensive analysis of the overall survivability of the Bradley with the proposed enhancements. The report is to include analytic data (vulnerability models) and the results of the actual shots taken during Phases I and II.

8. General Observations on Live Fire Test Program

1. Live Fire Testing is a useful test program to determine a weapon system's vulnerability to all types of munitions on the battlefield. This testing is useful in determining improvements to systems that might enhance survivability. This testing, however, is not designed to determine the system's ability to meet design or operational specifications.

2. Live Fire Testing should be conducted prior to full-scale production of systems. Live-fire testing should also be done prior to approval of major design modifications.

3. Live Fire Testing should be controlled and/or conducted by an independent agency -- that is, not the developer or proponent for the program.

4. The proper integration and reporting of live fire test and model results are crucial if decision-makers are to be provided with reasonable estimates of vehicle vulnerability.

I - JOINT LIVE FIRE PROGRAM

A. Background

The Joint Live Fire Test Program was chartered by the Office of the Under Secretary of Defense/Director, Defense Test and Evaluation in March 1984.

The program was established to examine aircraft and armored combat vehicles with the following program objectives:

1. Gather empirical data on the vulnerability of U.S. systems to foreign weapons and the lethality of U.S. weapons against foreign targets.

2. Provide insight into design changes to reduce the vulnerability and improve the lethality of U.S. weapon systems.

3. Enhance the data base available for battle damage assessment and repair.

4. Validate current vulnerability and lethality methodologies.

The priority aircraft survivability test objective is to assess air-to-ground attack aircraft including the F-16, F-15, A-6, AV-8B, AH-64, UH-60, MIG-23, and MI-24. The aircraft plan was submitted in March 1984, approved and funded.

The priority armor test objective was to determine the lethality of major caliber anti-armor munitions against first-line armored vehicles, including the T-62, M60-A3, T-72, and M-1 tanks; the M-2 (or M-3) Bradley Fighting Vehicles; and the Marine Corps Light Armored Vehicle.

B. Bradley Fighting Vehicle

The M-3 scout (5-man) or M-2 infantry (9-man) version of the Bradley Fighting Vehicle is designed to be a highly mobile transport vehicle. The armor of the Bradley Fighting Vehicle was designed to withstand damage from the weapons of up to 14.5mm caliber. This decision was made during the development of the Bradley Fighting Vehicle based on the belief that its mobility and tactical employment would reduce its vulnerability and increase its battlefield survivability.

The employment of the Bradley requires tactical operation in an environment when anti-armor weapons capable of defeating a tank will be present. The presence of these overmatching weapons (greater than the system was designed to withstand) have resulted in extensive Army studies of Bradley survivability. These studies showed potential enhancements through changes in armor or design modifications and through improved lethality of on-board weapons.

C. Bradley Live Fire Test Program

The Bradley live fire tests were to be conducted in two phases. The priority objective for Phase I tests was to quantify the lethality of major caliber anti-armor munitions, often referred to as overmatching weapons (i.e.,

capable of breaching the vehicle's armor), against the Bradley. In addition, data would be collected to update models used to predict overall vulnerability.

In carrying out the testing program, a building block approach was advocated and used by the Army. Testing began with controlled firings at a Ballistic Hull and Turret (BH&T, a vehicle with minimal internal componentry) and production M-3 Cavalry Fighting Vehicles containing inert ammunition. These tests focused on the isolation of individual damage mechanisms and component failure modes to gain a better understanding of how to enhance Bradley survivability and to identify where the models that estimate damage required improvement.

Testing concluded with 10 firings at combat-loaded M-3s containing live ammunition. These shots addressed the remaining uncertainties that could only be assessed through full-up tests. These uncertainties involved the reaction of fuel and ammunition and any possible synergistic mechanisms that might occur in full-up tests.

The objective of Phase II was to test the best possible means of reducing the source of Bradley casualties revealed during the Phase I tests. For Phase II, the Army planned a number of enhancements--reactive armor, spall liners, limited movement of ammunition--that would be tested. The outline test plan specified 34 total shots (17 each on 2 test vehicles); 14 shots would be repeats of Phase I shots, and the additional 20 would be into areas where enhancements were made.

On March 20, 1986 Phase II testing began, and eleven shots had been completed prior to test suspension on April 18, 1986.

In 1984 the Principal Deputy Under Secretary of Defense for Research and Engineering wrote that the armor community "has been unwilling to prepare a plan consistent with the objectives of the Joint Live Fire Test Program." He complained that relatively few full-up combat-configured tests were planned and that adequate preliminary testing had already been accomplished. In May 1986 this official confirmed his position to the investigative team, stating that at the time too much reliance had been placed on computer simulation. He stated, however, that he believed many of the problems centered on such issues as the OSD directing the military services, an Air Force colonel directing Army test programs, services funding their own testing programs, and a fundamental disagreement on how tests are to be conducted.

Although the Bradley was originally part of the formal Joint Live Fire Test Program, in 1984 OSD decided that the Bradley vulnerability tests would be conducted by the Army outside the framework of from the Joint Live Fire Test Program. The Army agreed to expedite and fund the testing program. Colonel Burton was invited by the Army to participate in the planning and execution of the Army tests.

A fundamental difference in the approach to testing exists between Colonel Burton, who advocates immediate full-up shots, and the Army testers, who have a systematic building block approach toward testing. Phase I testing was conducted, and Phase II testing begun without resolving this difference.

Despite the existence of memoranda stating the goals of the Joint Live Fire Test Program, no specific DOD regulations exist prescribing policy and procedures for the program. The investigative team found general agreement on the overall goals of the program but inconsistent understanding of how the program is to be conducted and what test methodology is to be employed. Detailed test plans approved by OSD supposedly serve as the overall program guidance for such tests. In the case of the Bradley, because a detailed test plan was never approved, many aspects of the test program were never enunciated. Phase I was conducted and reported to Congress in December 1985. The goals of the Phase II program were to determine the effectiveness of proposed enhancements and to determine shock effects on fire control components. Although the test report date set by Congress is June 1, 1986, a detailed test plan has not yet been approved by OSD.

Because only one program, the Bradley, was examined, the investigative team cannot conclude, without more extensive review, whether the problems identified in this report exist in other areas of the Joint Live Fire Test Program.

D. Models as Predictors of Vulnerability

The initial plan for the armored combat vehicle phase of the Joint Live Fire Test Program was approved by the Joint Technical Coordinating Group for Munitions Effectiveness in January 1985. Although this plan does not address the Bradley test program specifically, it does describe the Joint Live Fire Test Program and its relationship to overall armored combat vehicle vulnerability assessment.

The plan points out the following: In order to assess vulnerability with the greatest degree of accuracy, no substitute is available for live, full-scale testing to determine armored combat vehicle vulnerabilities. However, complexity (different hit locations, intricate and complex interiors, multiple physical phenomena); target response (a system comprising many subsystems); other constraints (lack of threat munitions); costs, etc. collectively make it difficult to acquire an adequate statistical base with which to make the assessment. To permit evaluation, therefore, testing must be conducted to provide critical input for calibrating evaluation models. These componentry models, which currently exist, are known as vulnerability lethality models. They are mathematical constructs that take into account the important interrelationships involved in the application of specific weapons against a specific vehicle and are used to estimate this effect over a wide range of circumstances based on data from a necessarily limited number of tests. The use of these models is required to evaluate prudently system vulnerability.

The plan discusses a six-step testing process as shown in figure 1. The first four steps, according to the plan, should be completed prior to conducting any live fire tests on vehicles loaded with ammunition and fuel. These include (1) characterization of the weapons and target vehicle; (2) obtaining data on effects of hits on critical components within the vehicle; (3) combining this data in the vulnerability model; and (4) calibrating the model (i.e., refining the model based on the data to improve its predictions) with tests on full-scale (minus fuel and ammunition) vehicles or surrogates. These four steps are needed to identify the areas of uncertainty and the additional information required to resolve these areas of uncertainty. Following this, full-up vehicles (step 5) can be tested to resolve the uncertainties, determine the magnitude of the expected damage, and check model predictions. Finally (step 6), with the results of the tests incorporated in the model, it can be used to assess overall system vulnerability for a variety of conditions of interest.

Colonel Burton does not believe the Army models are good predictors of vulnerability and, therefore, advocates more random full-up firings, using those results to predict Bradley vulnerability not the Army models. He cites two examples where the models did not predict actual experience: hits into fuel tanks on the M-113 in the Vietnam War and some Phase I test results for Bradley live fire tests.

The Army states that they continually update their models based on both test results and combat experience. In the two cases cited by Colonel Burton, the Army has made subsequent modifications to account for these events and now believes their models are better predictors of these events.

Many of the issues raised by Colonel Burton relate to the fundamental disagreement regarding the underlying process and the place and use of models in this process. These issues are described below.

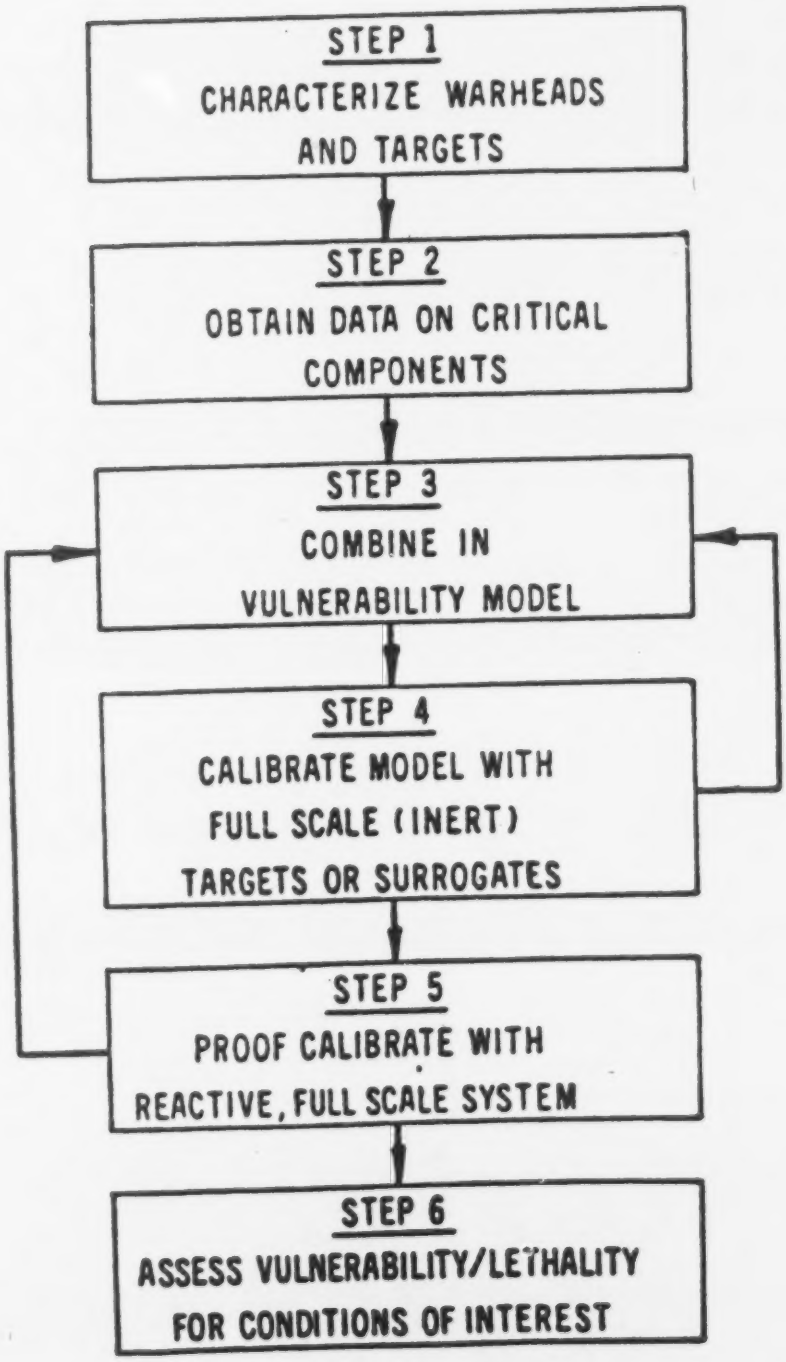


Figure 1. Testing Process

II - REPOSITIONING THE WATER CANS

A. Chronology

Colonel Burton says that "When FMC turned over the vehicles to the Army on March 16, two 5-gallon water cans were stowed in the left rear corner of the troop compartment. On March 18 Ballistic Research Laboratory directed TECOM [Testing Command] to reposition the ammunition stowage brackets and move the water cans so that they were directly behind the impact point and on the shot line for shot 1."

The investigative team, in looking at the overarching issue--did the Army move the water cans and then direct test shots into them to bias the results--focused on two distinct questions. First, what is the intended stowage location of the water cans according to official Army doctrine, and what is the Army's philosophy for their placement? Second, were shots directed into the water cans so as to reduce the vulnerability results reported to Congress?

The Bradley is produced in several versions. The "Baseline Version" contained a built-in 10-gallon water tank located on the vehicle's right-hand side rear sponson (area above the track). Because of the difficulty in cleaning this tank the Army changed to using two portable 5-gallon water cans. A review of the Army's stowage and strapping diagram for the M3A1, dated September 12, 1984, depicts the water cans positioned in the center of the left side of the vehicle near the turret (see diagram on Ballistic Research Laboratory display of shot scheme). In March 1986, when the test vehicles arrived at Aberdeen, however, the water cans were located on the left-hand side rear sponson.

The investigative team was unable to determine the location of the water cans during the Phase I tests but assumed they were located on the left rear sponson as they were just prior to beginning Phase II tests. Army officials first became aware of this incorrect stowage on March 9 while at an FMC meeting in California. A Ballistic Research Laboratory and an Army Materiel System Analysis Agency official together reported the location to the Bradley program manager who directed that the water cans be repositioned (in accordance with the engineering drawings for the M3A1 production version of the vehicle). FMC sent a representative to Aberdeen on March 18 to direct the repositioning of the water cans. An FMC interoffice memo dated March 10, 1986 documents that 25mm ammunition was stowed "at the aim point (turret center line)" and suggested that it would be better to move the ammunition and store inert items, including water, in this area. No one was able to provide rationale for the initial stowage of the water cans.

The Army positioned its water cans based on a philosophy that, to the extent possible, ammunition and fuel should be stowed away from the center (area) mass of the vehicle because this is the target area of trained enemy gunners. This philosophy is documented in a "Subjective Analysis of the IFV/CFV [Infantry Fighting Vehicle/Cavalry Fighting Vehicle]" done by Ballistic Research Laboratory on July 19, 1984. This analysis states "The aim point on

the BFVS will most likely be somewhere along the center line of the turret, regardless of whether the vehicle is in hull defilade and irrespective of the azimuth of attack. This comment on the aim point leads directly to the first point of discussion for the ammunition stowage; specifically, do not stow ammunition around the center of the vehicle."

Colonel Burton supports his position with statistics that are interpreted to show that hits occurring in combat are distributed over the entire vehicle and are not concentrated on the center mass of the lateral side of the vehicle. Thus, in Colonel Burton's view, placing the water cans near the center of the vehicle will not necessarily reduce the vulnerability. Colonel Burton further asserts that switching of the water cans and ammunition in Phase II was accomplished in order to reduce apparent casualties and was a deliberate attempt by Ballistic Research Laboratory to bias the test.

The investigative team did determine that the Ballistic Research Laboratory and Army Materiel System Analysis Agency officials who reported the location of the water cans were also the officials directly involved in selecting the Phase II non-repeat aim points. The Ballistic Research Laboratory and Army Materiel System Analysis Agency officials testified that they did not consider shot selection when they suggested the repositioning of the water cans, nor did they consider the new position of the water cans when they redrew the shot lines. They stated that they believed it was a coincidence that an added shot impacts the water cans.

On the question of the location of the shot lines in the test, Colonel Burton says "Eight of the planned 34 Phase II shots are aimed at the repositioned water cans." [Because 17 shots were planned for each vehicle (a total of 34 shots), this would mean 4 shots on each vehicle could strike the water cans.] Colonel Burton's position is based on a visual examination of the test vehicle and the shot scheme represented in the outline test plan that depicted shots impacting the center area of the vehicle. A detailed test plan, however, was not available.

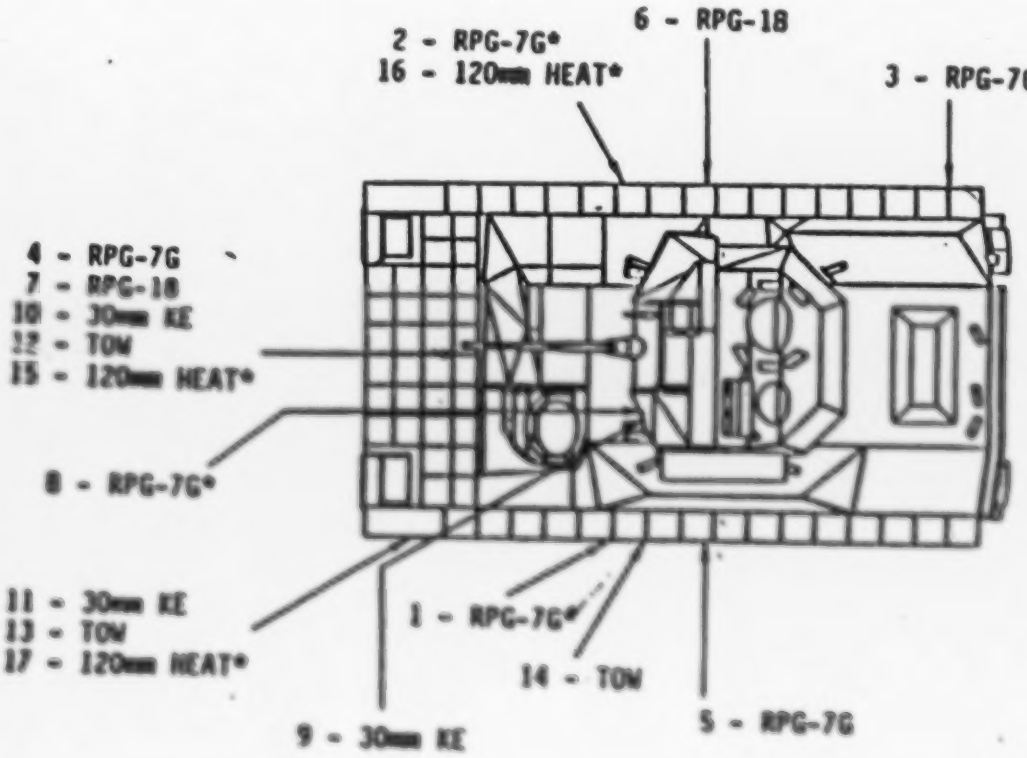
The Army's detailed test plan, as of this writing, is still in draft form, so no official shot plan has been submitted by the Army to OSD for approval. Ballistic Research Laboratory, however, prepared diagrams representing the shot lines according to their analysis. These diagrams show that one shot, shot #5 (a Rocket Propelled Grenade [RPG]), on each vehicle would penetrate the water can directly and another RPG shot (#1) on each vehicle might strike the cans but would first have to travel through a box of 25mm ammunition (see diagrams). The investigative team found that one additional RPG round's shot line (#6), not included on the diagram, could impact on right-hand side of the vehicle, penetrate through the vehicle, and hit the water can.

The draft detailed outline test plan states "Every attempt was made to select impact points that would test vehicle design and to determine the behind-armor effects on the vehicle. No attempt was made to exclude catastrophic shots. In fact, all of the shots have fuel, ammunition, personnel, or critical components on the shot line".

The investigative team found this not to be the case. It is clear that while all eight shots identified by Colonel Burton probably would not penetrate the water can, anywhere from two to six of the shot lines may intersect the water cans. Most Army witnesses stated that attempts were made to avoid catastrophic shots; that is, shots that were known to cause extensive damage. The investigation revealed that not all of the shots had fuel, ammunition, personnel, or critical components on the shot line. A shot into a water can does not necessarily have these items behind them.

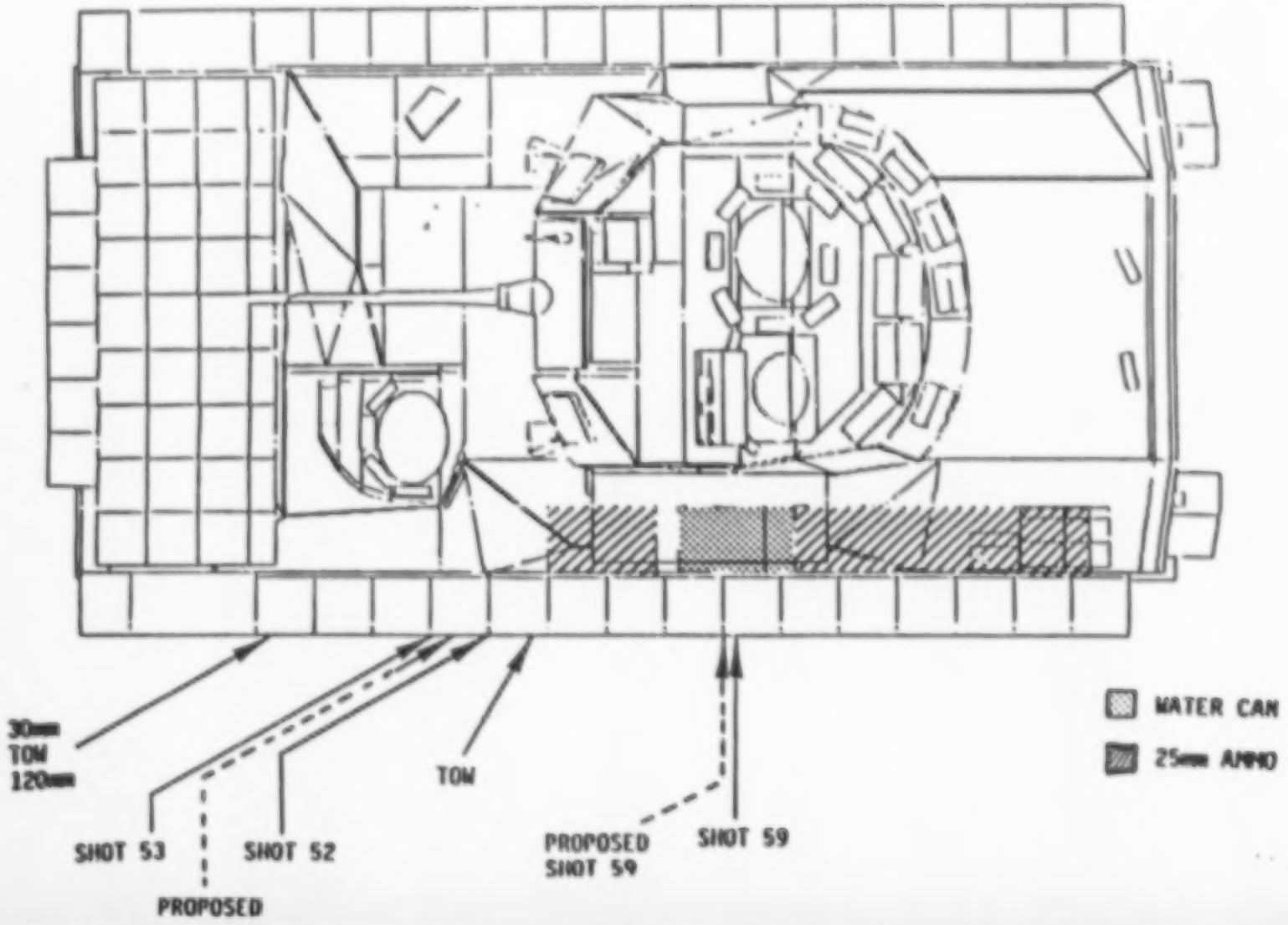
The Army, however, defends its shot plan by saying that because the RPG rounds were not expected to penetrate the enhanced armor, it really does not matter what is behind the armor.

PHASE IIA - ENHANCED VEHICLE FIRINGS



* Repeat of Full-up Baseline Shot

- SHOTS 8 AND 9 AGAINST HULL DEFILADE TARGET; REMAINING SHOTS FULLY EXPOSED TARGET (ISU TO BE REMOVED FOR SHOT 8)
- SERIES TERMINATED IF VEHICLE IS DESTROYED OR NO LONGER USABLE AS A TARGET
- FULL SUITE OF RAFAEL ARMOR WILL NOT BE AVAILABLE FOR ALL SHOTS; SUFFICIENT TILES WILL BE AVAILABLE TO COVER EFFECTS AREA
- TEST SETUP, PROCEDURES, AND INSTRUMENTATION SAME AS PHASE I TEST



BRL DISPLAY OF SHOT SCHEME

B. Effects

Colonel Burton says "...that the switching of ammunition and water can locations changes only the test results, not the actual vulnerability in combat. This is because:

a. The exposed area of ammunition has not been decreased.

b. The actual density of hits, based upon real combat results, is essentially the same for the old and new position of the relocated ammunition."

An Army issue paper (unsigned) stated in response to this statement:

"False; data shows that density of hits are based on location of the aim-point. The restowage move(d) the ammunition to the rear of the vehicle. The probability of a hit on the relocated ammunition is greatly reduced."

Colonel Burton bases his view on analysis of data from the Arab-Israeli wars, primarily 1973. This analysis is quite thorough showing the actual impact points and angles of entry on armored vehicles destroyed during this conflict. The data shows impacts distributed over the entire area of the vehicle. Colonel Burton presented a recent analysis by the Institute for Defense Analysis using this data, to determine what the probability of a hit would be on water cans located in the center of the vehicle versus water cans located in the rear of the vehicle. The analysis shows that there would be only a slight reduction in the probability of a hit striking ammunition. (See attached diagrams).

Army witnesses stated that armored vehicles in combat will experience a higher concentration of hits near the center of exposed mass of the vehicle and, for higher caliber weapons, concentrations will also be in the forward area of the vehicle. The Army view is based on interpretations from both combat and test range data (including the 1973 war, World War II, Viet Nam and developmental and operational weapons tests). Army witnesses stated they would not rely on any one study of combat data because all data is scenario dependent and not necessarily representative of a European conflict.

All of the non-repeat shotlines added by the Ballistic Research Laboratory in the Phase II test pass through the center of the vehicle. Army witnesses explained that U.S. and Soviet gunners are trained to aim at the exposed center of mass of a vehicle. Thus for each angle chosen by their method, they overlaid on the center of the Bradley a one standard deviation ellipse representing peacetime test range data on expected weapons dispersions. Army witnesses stated that the majority--68 percent-- of the shots in combat would fall within this area. Ballistic Research Laboratory then picked the exact impact point for the test shot somewhere within this area. With this method, the Army, Balistic Research Labora- tory, and Army Materiel System Analysis Agency witnesses explained why the test shots are concentrated at the center of

the vehicle, and why moving the water cans to the center would reduce the vulnerability of the vehicle.

Analysis of this method done for Colonel Burton by Institute for Defense Analysis points out several problems.

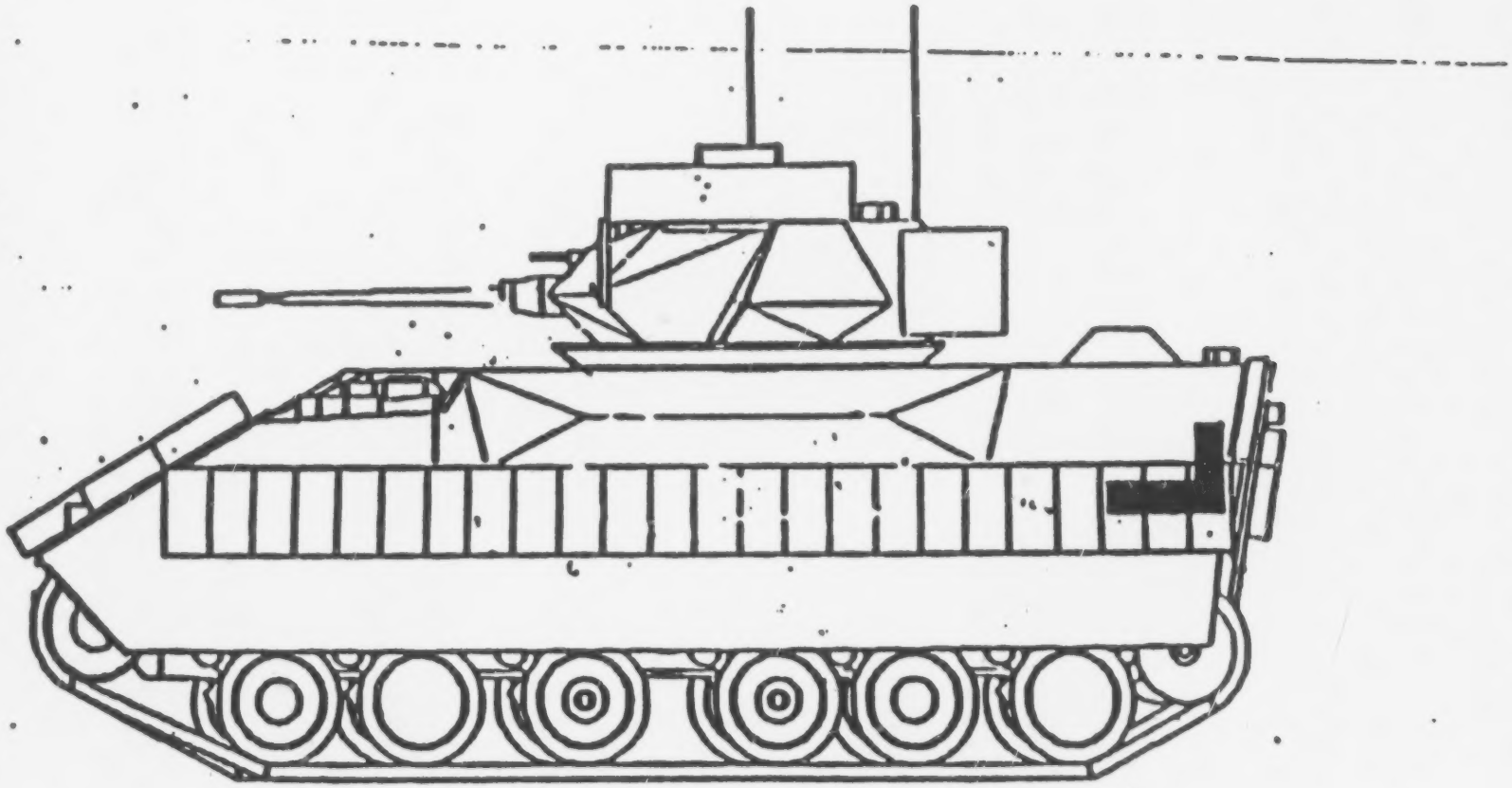
Firstly, Institute for Defense Analysis concludes that the Army analysts made a common statistical error that results in overstating the number of shots that would fall within a one standard deviation ellipse around the aim point. Institute for Defense Analysis analysts told the investigating team that this ellipse is a bivariate normal distribution and would only represent hits by 39 percent of all shots, not 68 percent. Recent discussion with Army analysts indicate they agree with Institute for Defense Analysis on this figure.

Secondly, Institute for Defense Analysis also calculated actual combat hits within this ellipse for one class of weapons and found that only 29 percent of the combat hits were within the ellipse. The Institute for Defense Analysis used combat data relied upon by both the Army and Colonel Burton.

The evidence reviewed by the investigative team supports the statement that the actual density of hits based upon real combat results is essentially the same for the old and new position of the relocated ammunition and water cans. Although the movement of the water cans to the center may not be wrong in itself, the actual impact of this move on the vehicle's vulnerability is small and should not be overstated.

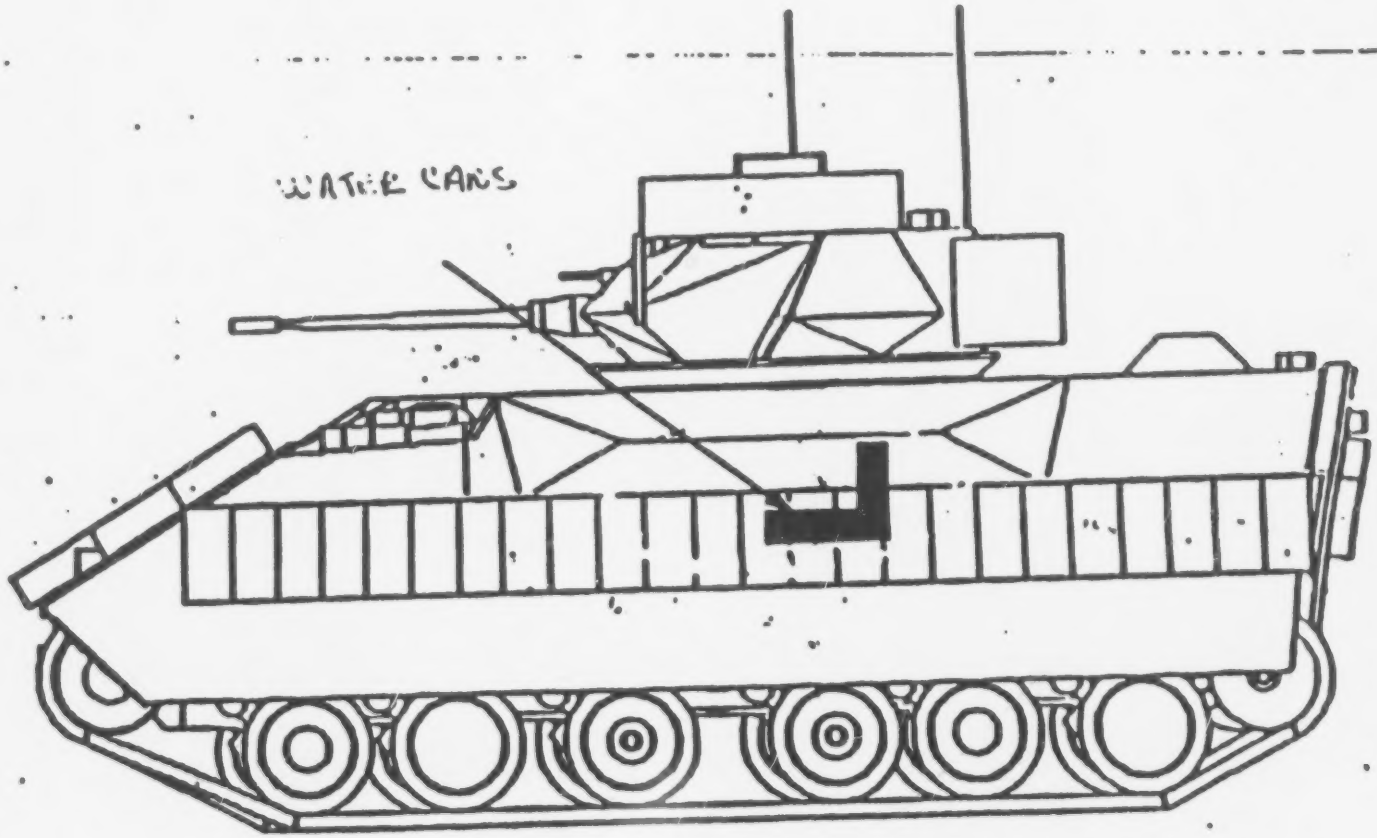
Little justification exists for using the Army's ellipse method to select aim points. The method seems to be an attempt to meet OSD guidance that shots be selected on combat hit distribution. The ellipse method does not do that.

DIAGRAM PROVIDED BY COLONEL BURTON (#1)



BASED UPON COMBAT HIT DISTRIBUTION, 99.3% OF SHOTS WOULD MISS THE WATER CANS -- LOCATED IN THIS ORIGINAL POSITION.

DIAGRAM PRESENTED BY COLONEL BURTON (#2)



BASED UPON COMBAT HIT DISTRIBUTION, 98.7% OF SHOTS WOULD MISS THE WATER CANS LOCATED IN THE NEW LOCATION.

III - SHOT SELECTION

Colonel Burton says that "Congressional, GAO, USDRE criticism about controlled aim points during Phase I led USDRE/TE to direct on April 1 that the additional Phase II shots be selected by random draw from combat hit distribution to prevent personal or systematic bias from entering the picture. The Army has ignored this guidance."

In examining this allegation, the investigative team focused on three questions: (1) What are the objectives of the Phase II test?; (2) What is the basis for the shot selection criteria?; (3) What is the actual guidance from OSD regarding shot selection?

A. Objectives for Phase II Test

Both the Army and Colonel Burton agree that the purpose of the Phase II test is to determine the effectiveness of several proposed survivability enhancements for the Bradley. In Phase I, all of the 10 shots fired at fully loaded Bradley vehicles were specifically selected to fill voids in the Army's computer models. Phase II consists of 17 live-fire shots against a fully-loaded vehicle. Seven of the 17 shots were to be repeats of Phase I shots where enhancements have been proposed. The selection of the additional 10 shots is in contention.

The Army believes that, due to the limited number of shots, a true statistical combat representation is not possible. Thus, their approach is to update their combat vulnerability models through live-fire testing and use the models to predict the contribution of the proposed enhancements.

Colonel Burton agrees that the number of shots is limited but believes that the live-fire tests provide significant data because the Army models are not accurate predictors. Colonel Burton believes that the results of the Phase I test (that is, the lack of correlation of predicted values with actual values of reported shots) support his position that the Army's models are not valid predictors.

Based on these differences, the Army and Colonel Burton disagree on the methodology for shot selection of the 10 additional shots. These differences represent two different approaches to testing weapon systems that have persisted throughout the Bradley test program. In Phase I, OSD ultimately agreed to proceed with the Army's methodology for selecting the shots.

B. Criteria for Shot Selection

Colonel Burton's position is that to avoid any perception of bias, shots should be selected randomly. As such, shots would be selected by random draw from a distribution derived from the 1973 Arab-Israeli war, Vietnam and World War II. Once selected randomly, proposed shots would be discarded if they did not hit areas on the vehicle where enhancements were to be made. Further, if all agreed that a particular shot would be a catastrophic kill, those shots

could be discarded if the final report denoted these shots as a catastrophic event.

Because of criticism of bias in the shot selection in Phase I, the Army decided to modify its approach for Phase II. For Phase II, the Army's objectives for shot selection were to determine the contribution of proposed enhancements to the Bradley. The Army's approach was to select shots that could be matched with areas of proposed enhancements as well as adequately represent attack angles that correspond to the highest proportion of expected combat impact locations derived from war data (the Army's data base includes Vietnam, 1973 Arab-Israeli War, World War II). The Army defined aim points based on the center of mass of the vehicle presented at each attack angle. The actual impact points were then selected from within one standard deviation of the chosen aim point in order to provide for the inherent inaccuracy of the weapons being fired. (The notion of accuracy based on one standard deviation around the aim point is derived from Army peacetime training data).

Analysis of this approach by the Institute of Defense Analysis shows that selection of aim points based on the center of mass and one standard deviation does not represent combat distribution data.

At the request of the Army, an independent assessment of both general approaches was prepared by the Los Alamos National Laboratory. The two approaches were characterized as random aim point selection (Colonel Burton) and deterministic aim point selection (Army). The Los Alamos assessment concludes that both test design approaches are widely used in scientific endeavors, and that both have strengths and weaknesses. The Los Alamos report recommends that a combination of the two approaches appears to be the best solution. Further, they recommend that test results need to be reported along with appropriate modeling results in order to avoid misinterpretation.

C. GAO Report

In its report reviewing Phase I, the GAO states that "Test conditions influenced the test results making the vehicle seem less vulnerable and the casualty rate lower than might actually be the case under combat conditions. Most of the 10 live-fire test shots were aimed to deliberately avoid striking the explosive elements of the stored ammunition. According to the Army, this was because the effect of such shots--total loss of the vehicle and the entire crew--was already well known....Had shots reflecting the combat distribution of hits been fired, the vehicle loss rate and estimated crew casualty rate might have been much higher."

The GAO staff explained that, in their view, the Army's approach to the shot selection was legitimate given that the Army includes in the final report a discussion of the effects of those shots that were excluded--firing shots into fuel and ammunition.

The GAO also states that "The Army used the Phase I test results to update its vulnerability models which predict the Vehicle's vulnerability in combat, but only a limited amount of the updated vulnerability information obtained from the models was used in preparing the report submitted to Congress...This data would have helped to provide a more realistic assessment of the Bradley's vulnerability."

In a letter to the GAO dated April 24, 1986, OSD replied to the GAO report, stating that "The Phase I tests, however, were not intended to produce complete vulnerability estimates. Complete vulnerability assessments will not be available until after Phase II tests." The letter further states, "The Phase II tests on the Bradley will be conducted similarly to Phase I, but are designed to collect data about the vehicle with survivability enhancements added to it. Data from both phases of the Bradley tests will then be fed into the vulnerability models and weighted by a combat distribution to estimate the casualties that would be experienced in combat situations."

D. Documentation of DOD Guidance

The Army submitted its first outline test plan to OSD on February 18, 1986. Although the first outline test plan generally identifies the proposed Phase II shots, it does not address the rationale behind the shot selection. On February 24, 1986, Under Secretary Hicks approved the outline plan subject to five conditions. The OSD approval does not discuss the shot selection scheme.

On March 20, 1986, the Army submitted a second outline test plan in response to the issues raised by Dr. Hicks' memo as well as those raised during informal discussions with the OSD staff. The March outline test plan provides a modified shot plan and identifies the Army's proposed shot selection criteria. The March 20th outline test plan clearly states that the tests would begin on March 20th. The Army notes that the first three shots--scheduled to be fired by March 27th-- would be duplicates of Phase I shots.

On April 1, in response to the March outline test plan, the Deputy Under Secretary of Defense for Test and Evaluation sent a memo to the Deputy Under Secretary of the Army for Operations Research. The April 1 memo provided the following guidance: "The shots planned for Phase II should either repeat the aim points from Phase I where improvements have been made on the vehicle or be selected at random from combat hit distributions in a manner similar to that recently completed by your M1A1 test planning team."

Firings against the Bradley began on March 20, 1986. The first four shots fired were repeats of Phase I shots. During the week of April 1st, two shots that did not repeat Phase I shots were fired at the Bradley vehicles. (The first shot occurred on April 1 and the second shot on April 2.)

The testimony provided by officials in OSD indicates that although the written guidance could have been interpreted as ambiguous, several conversations ensued between OSD and Army officials to clarify that the Army

was directed to select shots at random from the combat hit distribution data, for those non-Phase I shots.

Testimony received from Army officials indicates that the guidance was ambiguous. Thus, the Army assumed that they had received approval to proceed with their preferred shot selection approach. Army witnesses state that the Deputy Under Secretary of Defense for Test and Evaluation did not discuss this issue with the Army until April 18, 1986.

At this time, the conflict concerning the shot selection scheme apparently has not yet been resolved.

IV - PATTERN OF IMPROPER BEHAVIOR

Colonel Burton said, "Since 1984 there has been a pattern of key BRL [Ballistic Research Laboratory] attempt to reduce the apparent casualties caused by the Bradley during tests, including:

"a. Watering the dummy uniforms in 1984.

"b. Selecting the 5-man M-3 configuration to test in 1985 instead of the 9-man M-2.

"c. Using selected instead of random aim points during Phase I.

"d. Switching water can and ammunition in Phase II."

The investigative team was unable during this investigation to explore fully all of Colonel Burton's assertions in this area. Of those allegations investigated--shot selection methodology and interior stowage of water and ammunition and related issues--the team found that if a pattern developed, it was one of a long-standing fundamental disagreement over testing methodology and, more importantly, the inability of OSD and the Army to reach an agreement on how the test is to be conducted.

A June 14, 1984 memorandum from Colonel Burton to Deputy Under Secretary James Wade notes,

"Over the course of the past 6-8 months, the Ballistic Research Laboratory has made decisions and taken actions in the conduct of this program which, when viewed as a whole, have resulted in less realism than we requested as a condition of [the Army] funding the test, less realism than was easily achievable under the circumstance, and less realism than is needed if any meaningful conclusions are to be drawn with respect to aluminum vaporifics, infantry casualties andthe overall combat vulnerabilities of the M-2/3 and M-113 vehicles. In many cases Ballistic Research Laboratory's decisions and action selectively reduced the severity of the behind armor effects noticed. As a result, Ballistic Research Laboratory analyses and inferences on the meaning of the test results...will necessarily be suspect...."

Appended to the memo is a list of 18 separate actions taken by Ballistic Research Laboratory that Colonel Burton claims reduced the behind-armor effects of the test shots. These include: static detonation of weapons rather than dynamic impacts, using weapons that are too small, down-loading propellant in HEAT rounds, reducing the velocity of weapons by firing them too close, and using selected shots and angles.

On April 24, 1986 Colonel Burton provided the team with a memo that states, in part, "Over the past two years we have had numerous disagreements with the Army over the conduct of the Bradley Live Fire Vulnerability Tests and aluminum 'vaporifics' tests." The memo goes on to list 13 test-related issues that

Colonel Burton says the Army eventually agreed to and that were in accordance with the OSD direction. The majority of these issues directly resolve those areas in dispute in the June 1984 memo referenced above.

Further investigation would be necessary to fully explore all other allegations of irregularities by Ballistic Research Laboratory charged by Colonel Burton.

V - MINIMUM CASUALTY BASELINE VEHICLE

In an April 8, 1986 memo for The Record, Colonel Burton says "Two months ago the Army agreed in principle to test a third vehicle, one with all fuel and ammunition removed from the troop compartment and stored either externally, or in externally vented compartments....The Army informed us that the vehicle will not be ready for test until November, and test results won't be available until February 1987....It was made clear in this meeting that the Army does not want any competition with their reactive armor concept. They have made up their minds before all test results are in."

In examining this allegation, the investigative team focused on two questions: (1) What is the nature of the Army's commitment to test the Minimum Casualty Vehicle; (2) What is the OSD direction regarding testing of this vehicle, and incorporation of test results into production decisions for future enhancements to the Bradley?

In Colonel Burton's view, the purpose of Phase II is to test the best possible means of reducing the sources of casualties revealed in the Phase I test. Thus, he believes that the Army's proposed enhancements should be compared with a baseline vehicle to determine which concept produces the fewer casualties. Because fuel and ammunition stored inside the vehicle produce greater casualties, Colonel Burton proposed a test configuration where all of the fuel and ammunition would be stored externally. Colonel Burton proposed the Minimum Casualty Vehicle as a test of a concept, not as a configuration for a production vehicle.

Colonel Burton believes that this concept vehicle could be made available in three months of its initiation. His estimate is based on conversation with the Project Manager for the Bradley vehicle and with technicians at Aberdeen Proving Grounds. The Project Manager disagrees with Colonel Burton's estimate and states that his original estimate of three months was not based on the current description of the Minimum Casualty Vehicle.

The Army says that it is committed to testing the concept of the Minimum Casualty Baseline Vehicle as an approach for making future modifications to the Bradley beyond the current 6,882 vehicle program or for improving future armored vehicles. A memo from Commander, Army Material Command states that "The current development program for the addition of reactive armor to the Bradley has potential for high payoff and we should not slow down this development effort because of the OSD proposed design. The production decision is scheduled for March 1987, after the testing of the OSD vehicle could occur if we move out now [sic]."

The Army proposes to test the OSD configuration after the current series of Phase II tests are completed because it believes that eight months will be required to design and build the vehicle.

The Army's rationale for an eight-month design and development period is that: (1) several operational problems (such as access to the ammunition by

troops located inside the vehicle) need to be resolved before a yehicle is fabricated for testing; (2) the test vehicle needs to be one that is ready for production if it proves to be the best solution for reducing casualties.

The OSD direction to the Army regarding the Minimum Casualty Vehicle is clear. On February 24, 1986, the Under Secretary of Defense for Research and Engineering directed that "No reports should be issued and no production decisions made on final configuration changes until test results from this configuration are available and compared to the test results from the configurations proposed in your Outline Test Plan."

Throughout the discussions between the Army and OSD regarding the Minimum Casualty Vehicle, the Army has been concerned that the fiscal year 1986 Department of Defense Authorization Act requires that the final Phase II test report to Congress must be provided by June 1, 1986. Thus, the Army has argued that the two tests be decoupled and that a report be submitted covering only the test results of the Army's proposed enhancements.

The direction from OSD is clear on the testing of the Minimum Casualty Vehicle and its effect on the required report to Congress. On February 24, 1986, OSD directed that "if it is necessary to seek relief from Congress on the June test report requirement to accomodate (sic) these results and comparisons, then we will initiate that action."

Based on the testimony received by the investigative team, the conflict over this issue has not yet been resolved, notwithstanding previous OSD direction. The Under Secretary of the Army apparently intends to request that the Under Secretary of Defense reconsider the previous position. This would represent the second official appeal of the OSD direction.

ADDITIONAL VIEWS

The investigation team agrees on the recommendations in the report. However, there is some disagreement over the text of the report and the conclusions.

It may not be clear from the report that the evidence examined by the team substantially supports four of the five key statements in Colonel Burton's memos. That is:

1) The switching of the ammunition and water can location does not significantly change the vehicle's vulnerability in combat, but it could change the test results;

2) The Army did ignore the April 1 OSD guidance that additional Phase II shots be selected by random draw from combat hit distribution;

3) From two to six of the planned 34 Phase II shots are aimed at the repositioned water cans. (It is possible that eight are aimed at the cans, but the team could not verify that.)

4) The team could not prove or disprove a pattern of key BRL attempts to reduce the apparent casualties in the Bradley tests.

5) The evidence supports Colonel Burton's claim that "the Army does not want any competition with their reactive armor concept. They have already made up their minds before the test results are in." General Thompson's words from 17 March 1986 are "..we should not slow down this [reactive armor] development effort because of the OSD proposed design." Yet, the full-up, live-fire tests have revealed substantially problems with the BRL reactive armor design. The BRL's component testing--using static detonations fixed to the armor--did not predict these problems.

Was There Bias?

The report concludes that "... no evidence of intent to bias the test results was found." While the team has no proof of bias, there is evidence which raises questions about the impartiality of the shot selection scheme. While those involved seemed well-intentioned, the way these tests were

conducted seems inconsistent with objective testing. Four examples of that evidence follow.

(A) The two Army officials in charge of selecting aim points for Phase I are the officials who suggested moving the water cans and then redrew the test plan to include a shot directly into the cans.

- The two officials met with several Army officers and with FMC officials to discuss the Phase II test on March 9, 1986 at FMC headquarters in San Jose, CA.
- During the meetings the officials suggested repositioning the water cans.
- During the week of March 10, the officials met again. They again discussed the repositioning of the water cans. In response to criticism of their shot selection method, they redrew the shot lines for the Phase II tests. They added shot #5 which has an impact point in the center of the repositioned water cans.
- On March 18 an FMC official repositioned the water cans on the test vehicles at Aberdeen with the assitance of Test Command (TECOM) technicians.
- On March 20 the first test shot was fired. In all, three of the shots fired had shotlines which intersect the water cans.

As the report notes, these officials believe it is a coincidence that shot #5 impacts at the center of the water cans.

(B) The team found no evidence that the repositioning of the water cans was included in the enhancements proposed by the Army for the test vehicles in Phase II.

Nor is the repositioning of the water cans discussed in any memos about the Phase II tests (including a detailed Army memo summarizing the March 9 meeting at FMC) until immediately before the move was made. Nor was the repositioning mentioned to Colonel Burton when he visited FMC on March 11. While such documentation may exist, none was provided the team despite repeated requests.

As the report notes, we do have a 1984 memo and diagrams that indicate Army plans to reposition the water cans on future M3 Calvary Fighting Vehicles. The diagrams do not show this change for M2 Infantry Fighting Vehicles.

It is not clear how this production change relates to the test vehicles. It does not appear to be part of the test package. When FMC completed its three weeks of modifications to the test vehicles, the water cans were in the left rear.

(C) Even so, moving the water cans would not be a significant event if so many shotlines did not intersect the area.

The team report concludes (1) that moving the water cans does not reduce vehicle vulnerability and (2) that the BRL method for selecting shots for Phase II is not valid. How then, does one explain the shot selection? The testimony of four sets of independent experts ranged from bemusement to suspicion. All were concerned about the number of shots directed at the center.

The report should more clearly explain that BRL method results in more shots at the water cans than can be justified by combat data. IDA's data show that in combat 1 out of 100 RPG's fired from the left would hit the water cans (1.3%). In the BRL test at least 1 out of 2 RPG's fired from the left would directly hit the water cans (50%). Both RPG's (100%) have shotlines which intersect the water cans.

IDA analysts told the investigation team that if these shots at the water cans were to be taken as representative of combat hits, it would create a misleading impression of the vehicle's vulnerability.

(D) The Los Alamos report states that the BRL approach may introduce biases into the estimation of kill probabilities.

"The BRL objective of assessing vulnerability," the Los Alamos team says, "does not lead directly to any criteria of where to locate the shots...we conclude that the modeling approach offers little guidance in choosing aim points and that the selection criteria are difficult to explain to critics." Further, "it is possible, using this approach, for unsuspected or rare events or combinations of events to go undetected because test design may preclude their discovery."

On the other hand, the random shot approach will provide "an unbiased estimate of kill probabilites," and "the existence and consequences of unanticipated vulnerabilities have a chance of being demonstrated dramatically in full scale tests." The disadvantage of random shots is that one cannot extrapolate to a more general model with precision. If avoiding biases is the goal, then the random shot approach would seem to be preferable over the BRL method.

Was the Transfer of Col. Burton Retaliatory?

The transfer of Col. Burton does not appear to be routine. Further Congressional investigation is warranted to assess the propriety of the transfer and its wider implications.

1.) The transfer at this time is almost certainly to have a chilling effect on others in DoD who question the effectiveness of institutional procedures, particularly in the testing field. It is comparable to the transfer of the rocket engineers who tried to stop the disastrous launch of the space shuttle Challenger.

2.) Colonel Burton obeyed military orders which assigned him to various posts in the Washington area over the past 16 years. It is not clear how this compares with other officers in his field or his department. While this situation may have required adjustment, the timing of the transfer and the exemption from the freeze on transfers are suspect, particularly in light of other events preceeding the transfer.

- In a Memorandum for the Record dated 22 December 1985, Col. Burton states that he met with the Under Secretary for Research and Development in his office a few hours before Burton was to meet with members of the House Armed Services Procurement Subcommittee. The Secretary, according to Col Burton, "...told me that writing independent reports on test results may have been my job in the past, but from now on I was not to write anymore 'independent' reports....Dr. Hicks then advised me that if he ever received anymore telephone calls from Congressmen about me, that I would be fired."

If this is accurate, then the Secretary may have violated Federal laws protecting an employee's right to disclose information to Congress.

Col. Burton's supervisor at the time was present at the meeting in the Secretary's office. He testified that the meeting got "heated," but denies that the Secretary threatened to fire Col. Burton.

- Col. Burton also states that "Following the Hick's meeting I returned immediately to my office where I passed on to my office colleagues Dr. Hick's accusations and directions." Gen. Jones, Col Burton's immediate superior was present at that time. Further investigations should verify the accuracy of these incidents and question why Col. Burton's superior's, once informed of the situation, did not seek compliance with and enforcement of the applicable laws and regulations as required by law.

3) Col. Burton was not officially informed of the possibility that he might be allowed to stay in charge of the Bradley test program if he accepted the transfer until 15 minutes after the deadline had passed for him to either accept the transfer or resign. This is confirmed by Col. Burton's two superiors, including the official who actually handed Col. Burton the written offer.

Thus, official DOD statements in letters to Members of Congress that Col. Burton was notified of this possibility on April 7, and that Col. Burton's resignation "preempted" this possibility appear not to be correct.

Is There A Pattern? Is There a Policy?

The water can incident must be judged in the context of the conflict between the BRL test methods and the JLFT program attempts to test in a more realistic manner.

The most serious statement made by Colonel Burton in his 15 April memo is that since 1984 there has been "a pattern of key BRL attempt to reduce the apparent casualties caused by the Bradley during tests."

The evidence the team examined suggests that there is a pattern of BRL methods which have had the effect of reducing the apparent casualties reported from these tests. Further investigation is required to determine whether this pattern is an intentional attempt to bias the results or is merely the natural consequence of the test methods employed by BRL.

The JLF approach was backed at the highest levels of DOD in 1984. Deputy Under Secretary Wade wrote:

"Last fall OSD proposed, and the Services unanimously agreed to the Joint Live Fire Test Program. The stated purpose of the program was to test the lethality of U.S. weapons against combat configured Soviet vehicles and to determine (and correct where possible) the vulnerabilities of combat configured U.S. vehicles to Soviet weapons. The program was concerned with two areas, aircraft and armor systems.

"**The need for this program was recognized by all,** since no current front line U.S. system (armor or aircraft except A-10) has ever been tested (through a formal test program) in a combat configuration for vuonerabilities to live Soviet weapons. **For the past twenty years, lethality/vulnerability assessments have been almost entirely based upon computer analysis with little or no full scale combat configured vehicle test results to support the assessments.**' [emphasis added] (Wade memo to Joint Logistics Commanders, 24 August 1984)

The aircraft tests have gone smoothly, but the armor tests were problematic from the beginning. The report notes a June 1984 memo from Col. Burton criticizing BRL methods in the 1984 tests.

The OSD observer of these tests confirmed many of Col. Burton's observations. The team has his four volume description of the 1984 tests, his 12 page memo to the team, and his direct testimony. None of this evidence is mentioned in the report.

The witness testified that BRL's actions almost always resulted in lessening the results of the test shots and rarely if ever resulted in more severe behind armor effects. He told the investigative team that OSD could have gotten much more information if the tests had not been conducted in this fashion. In a memo to the investigation team, this witness stated that the same shotline was used for 14 out of 15 shots in the tests and "was about the most benign shot line available anywhere in the crew compartment," avoiding all ammo, missiles, fuel and crew positions.

Citing his experience as a testing expert--he ran the most extensive anti-armor test ever conducted in peacetime in this country--the witness scoffed at Army claims that random shots at combat loaded vehicles would be too expensive. He estimated he could run the Bradley test with 6 worn out vehicles or ballistics hulls in a few months for $50 million. This would be much less expensive, he claimed, than the component testing has been. He pointed out that after nearly two decades of testing the Bradley, the modeling approach still has not yielded a reliable picture of the vehicle's vulnerabilities.

He specifically supported Col. Burton's claim that watering the dummies in the tests reduced the apparent casualties. He noted that watering the dummies (or more commonly, removing the combat fatigues from the dummies so they would not catch fire) was a minor action compared to selecting aimpoints on the vehicle which specifically avoiding hitting ammunition and fuel.

The team had an extensive interview with the BRL director of these tests. He vigorously disputed Col. Burton's statements. Specifically, he claimed that the burning dummy spoiled the test and was watered down to bettter isolate the test factors. The overall BRL rational for its methods is contained in the team's report.

The concerns of Col. Burton and the OSD observer were shared by Secretary Wade who wrote:

"In November 1983, the JTCG was asked to prepare program plans for the aircraft and armor phases. The aircraft plan was submitted in March 1984, approved and funded. It was responsive to the objectives of the program....

The armor community of the JTCG, on the other hand, has been unwilling to prepare a plan consistent with the objectives of the Joint Live Fire Test Program They have recently submitted a proposal which calls for spending $16M conducting literally thousands of preliminary tests on inert, (no fuel, no ammo, no hydraulic fluid) targets to 'characterize' warheads...etc...**This approach is not consistent with the purpose of the JLF, which is to determine the lethalities/vulnerabilities of combat configured equipment by actual test, not by modeling.**" [emphasis added] (Wade memo to JTCG, 24 August 1984)

In September 1984, Secretary Wade again complained that a series of Army actions, taken together,

"...indicate a continued reluctance to conduct full scale vulnerability tests of combat configured M-2/3 vehicles, a reluctance which, quite frankly, I do not understand." (Memorandum to the Assistant Secretary of the Army, 5 September 1984)

Secretary Wade noted in his interview with the investigative team that a compromise was worked out with the Army and the program seemed to be running well in early 1985. He called the JLFT program a "much needed step forward." He said, "the Bradley program had been heading for disaster...it took a live-fire test to get people to wake up."

The team's report notes that at present the Army has agreed to change many of its test methods in Phase II. But these methods are still used in other tests and the changes may only be temporary.

Why Not Rely on Computer Models?

The team report contains an extensive discussion of modeling. The alternative deserves equal space. Empirical evidence of the consequences of relying extensively on models follows:

"Our weapon systems today are procured with computer-based vulnerability/lethality estimates, little firing data and no live firing results. What are the consequences of not conducting realistic-combat live fire testing? When actual combat occurs, we discover, too late, serious shortcomings in our weapons systems; shortcomings which cost lives.

There are many accounts from WW II, Korea and Vietnam where U.S. "bazookas" failed to stop enemy tanks due to inadequate warheads. In WW II, Korea and Israel, U.S. tanks proved excessively flammable and vulnerable. The Israeli experience of 1973 showed that the U.S. M-60 burned or blew up twice as often when hit as the British Centurion, and more often than its predecessor, the M-48. Concern over excessive casualties caused the Israelis to make several changes to ther M-60s: different hydraulic fluid, fire extinguishers, special armor packages, etc...

In Vietnam, U.S. fighters also proved to be unnecessarily flammable and vulnerable. Fire and explosion caused the losss of at least 60 percent of the 5,000 U.S. aircraft downed in Vietnam. During the course of the war, survivability improvements kits had to be hastily developed and installed on fighters such as F-4 and F-105 to reduce their vulnerability.

In 1982, Congress directed a competitive 'shoot off' between candidate modern day bazookas to determine which one the Army would procure for tis infantrymen to kill tanks. Six candidates were tested, and a winner was selected, the AT-4. Over 400 rounds were fired during that major competition, yet not one round was fired against an actual tank...

As a consequence of not doing combat-realistic live fire testing, we have no idea whether today's 'bazooka,' tanks or first line fighters have improved this situation. The Joint Live Fire Test Program was initiated by OSD in 1984 to answer this question and to assist in making sure real improvements happen."

(Statement by Col. James Burton to the Procurement Subcommittee, HASC, 18 February1986)

Conclusion

The pattern of BRL and Army actions raises fundamental questions about the realism and independence of our weapons testing.

The Research and Development Subcommittee received extensive testimony in December and January from a senior member of the professional staff indicating that the pattern revealed by the Bradley test is not unique. He testified that, "the test and evaluation process is seriously flawed when the Pentagon repeatedly obligates millions and in some cases billions of dollars in defense appropriations before we find that the system does not work."

The investigation team report, taken together with these additional views, should be cause for concern. Since the Committee relies so heavily on test reports when considering its authorizations, the Committee should consider both an extensive GAO investigation and a series of Committee hearings on the reliability of test methods and practices currently in use.

Joseph Cirincione, HASC Staff

INTERVIEWS

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Mr. Charles Watt, (Previous job) Acting Deputy Under Secretary of Defense for Test and Evaluation

Brigadier General Don Jones, Deputy Director for Test and Evaluation

Colonel James Burton, Director, Joint Live Fire Test Program

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Honorable James Ambrose, Under Secretary of the Army

Mr. Walt Hollis, Deputy Under Secretary of the Army for Operations Research

Lieutenant General Louis Wagner, Deputy Chief of Staff for Research, Development and Acquisition

Lieutenant General Quinn Becker, the Surgeon General of the Army

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